DOCUMENT RESUME

ED 142 404 SE 022 655

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TITLE	Problem Format Study. SMESG Working Paper No. 2.
INSTITUTION	Stanford Univ., Calif. Stanford Mathematics Education Study Group.
REPORT NO	SMESG-WP-2
PUB DATE	Jul 69
NOTE	12p.; Not available in hard copy due to marginal legibility of original document; Tests 3001, 3002, 4045, and 4046 removed due to copyright restrictions
EDRS PRICE	MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS	Addition; *Basic Skills; *Educational Research; Elementary Education; *Elementary School Mathematics; *Error Patterns; Instruction; Mathematics Education; Multiplication; *Number Concepts; Subtraction
IDENTIFIERS	Research Reports

ABSTRACT

This study compared the error patterns of third- and fourth-grade children on addition, subtraction, and multiplication exercises in horizontal and vertical formats. The research design used parallel eight-item tests for each operation; the only difference between items on parallel forms was the formal (horizontal or vertical) of the computational problems. Data were summarized for the entire group and for two subgroups defined as low and average socioeconomic status (SES). In general, the error rate was higher on horizontal format problems. Over all problems, the average SES group performed better than the low SES group. Appended to the report are data summary tables, a testing schedule, and copies of the tests. (SD)

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MAY 27 1977

July, 1969

Working Paper No. 2

By: Max Jerman

Subject: Problem Format Study

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I. Introduction

Addition, subtraction, and multiplication exercises, in horizontal and vertical format, were given to third- and fourth-grade students. The purpose of the study was to compare the error rates on identical combinations when presented in different formats to students in both average and low socio-economic areas.

II. Procedure

Two forms of each set of exercises, a horizontal form and a vertical form were prepared by SMSG for use in this study.

Each test consisted of two parts, designated A and B. Form 3001-H, Part A, was horizontal addition at the third-grade level. Part B of the same test was horizontal subtraction at the third-grade level.

Form 3002-V, Part A, was vertical addition at the third-grade level. Part B of the same test was vertical subtraction at the third-grade level.

Form 4045-H, Part A, was identical to 3001-H, Part B. It was given to fourth-grade students. Part B of 4045-H was horizontal multiplication at the fourth-grade level.

Form 4046-V, Part A, was identical to 3002-V, Part B, and was given to fourth grade students. Part B of 4046-V was vertical format multiplication exercises at the fourth-grade level.

A copy of each test is attached. The example below illustrates the difference in format between the two forms of the test.

Form 1	Form 2
$\begin{array}{r} 57 \\ +\ 49 \\ \hline \end{array}$	57 + 49

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Tests for all schools were randomized for distribution to students for each grade level, using a table of random numbers (Fisher and Yates). The experimenter handed out each test to each student individually by row. All tests were given during morning hours, before noon according to the attached testing schedule.

Instructions to the students were read or quoted from memory as follows:

> Good morning. In just a minute I am going to hand each of you a short test. The purpose of this test is not to grade you but to help me learn which of the problems are more difficult than others for students at your grade level. The tests will take only 8 minutes on each part and there are only two parts so it won't take very long to finish them.
>
> It is important that we all start at the same time, so when I hand out the tests, just leave them on your desk until we go over the instructions together.
>
> (hand out tests)
>
> Some of you have noticed that the tests are not all the same. This is because I am trying to find out which problems are difficult for you and which are easy. I want you to do your best.
>
> Does everyone have a pencil?
>
> Now I will read the instructions on the test to you. You follow along.
>
> (read the instructions)
>
> Are there any questions?
>
> Please do your work on the test page.
>
> Do not go on to Part B until I tell you to do so.
>
> All right, begin.
>
> (When 8 minutes have elapsed, stop the class. Have everyone lay their pencils down.)
>
> (After 8 minutes, stop the class and read the instructions for Part B.)
>
> (After 8 minutes, have everyone stop and lay their pencils down.)
>
> (Collect the tests.)

III. Subjects

Principals in the selected schools were contacted initially by telephone to secure permission for testing students in the project. In each case, approval was obtained after the purpose of the program was explained. All schools, four in each socio-economic area, were public schools located within a 12-mile radius of Stanford University.

The first visit by the experimenter to each school consisted of a meeting with the principal at which time the tests were examined and their purpose reviewed. An appointment was made for testing at each grade level. Information on participating schools is attached.

In the four average socio-economic-area schools the population consisted of 300 third-grade students in 11 different classes and 330 fourth-grade students in 12 different classes. In the four low socio-economic-area schools the population consisted of 245 third-grade students in 9 different classes and 260 fourth-grade students in 12 different classes. There were 50 third-grade students and 102 fourth-grade students in mixed third-fourth and fourth-fifth combination classes.

The sole criteria for pupils selection was socio-economic level.

IV. Results

The data were summarized by grade level, part (A or B), and form for each socio-economic class, and mean number of items correct for each form on each part. There were 8 items in each part. Differences in the mean number of items correct on each part for each form were computed using the following t ratio (Hays, 1963, p. 317):

$$t = \frac{(M_1 - M_2) - E(M_1 - M_2)}{\text{est } \delta_{\text{diff}}}$$

where est. $\delta^2_{M_1} = \frac{s_1^2}{N_1 - 1}$, est. $\delta^2_{M_2} = \frac{s_2^2}{N_2 - 1}$ and

$$\text{est. } \delta_{\text{diff}} = \sqrt{\text{est. } \delta^2_{M_1} + \text{est. } \delta^2_{M_2}} .$$

This t value may be referred to a normal distribution since the sample was quite large and both populations were assumed to have normal distributions and standard deviations.

In every scale except 4B in SES-1 (low socio-economic area) the mean number of correct exercises for vertical format problems was significantly higher than the mean number of correct exercises for horizontal format problems. As indicated by the means on scale 4B, many students were not able to solve the multiplication exercises presented in this scale.

The SES-2 (average socio-economic area) group had mean scores which were high compared to the number of items on each scale, 8, indicating a large number of students "topped out" the test, particularly scale 4A, subtraction, which was identical to scale 3B. The SES-1 group apparently did not "top out" any scale, in fact the reverse was nearly the case for scales 3A and 4B.

The item analysis statistics for each scale are presented in Table 2. The p values indicate proportion correct. Adjusted p's indicate proportion correct when no-tries (N.P.) were deleted from the data.

It is interesting to note the highest per cent of problems not tried were those in horizontal format. The error rate was also apparently higher for horizontal format problems in general.

The mean number of problems correct for children in average socio-economic areas was significantly higher ($t = 10.06$, $df = 7$, $p < .001$) than the mean number correct for children in the low socio-economic area.

TABLE 1

Mean Number Correct and T-scores for each
Scale by Socio-economic Class

		SES-1			SES-2		
GRADE	PART	HOR.	VERT.	t	HOR.	VERT.	t
3	A	2.513	3.727	4.68***	4.757	6.408	6.30***
3	B	4.000	5.193	4.61***	6.017	6.792	3.23***
4	A	4.903	5.558	2.97**	7.208	7.562	2.80**
4	B	3.558	3.897	1.46	6.169	6.546	1.76*

For a one-tailed test

* $p < .05$

** $p < .01$

*** $p < .001$

$p < .07$

TABLE 2

Summary Data for each Item in each Scale

	Item No.	3001-H P's	3002-V P's	3001-H ADJ P's	3002-V ADJ P's	3001-H N.S. BIS	3002-V N.S. BIS	3001-H Per cent N.T.	3002-V Per cent N.T.
Part A Addition	1	0.917	0.900	0.917	0.900	0.377	0.345	0.0	0.0
	2	0.457	0.804	0.484	0.809	0.637	0.571	5.660	0.714
	3	0.347	0.614	0.371	0.625	0.447	0.649	6.415	1.786
	4	0.494	0.579	0.530	0.587	0.703	0.928	6.792	1.429
	5	0.438	0.571	0.472	0.580	0.707	0.766	7.170	1.429
	6	0.332	0.504	0.373	0.515	0.747	0.792	10.943	2.143
	7	0.294	0.546	0.270	0.569	0.665	0.811	7.925	3.929
	8	0.253	0.454	0.299	0.477	0.771	0.769	15.472	5.000
Part B Subtraction	9	0.974	0.968	0.977	0.971	0.528	0.742	0.377	0.357
	10	0.804	0.836	0.813	0.839	0.582	0.778	1.132	0.357
	11	0.721	0.886	0.737	0.889	0.783	0.774	2.254	0.357
	12	0.694	0.657	0.705	0.662	0.504	0.686	1.509	0.714
	13	0.347	0.464	0.365	0.471	0.721	0.715	4.906	1.429
	14	0.623	0.861	0.668	0.883	0.701	0.726	6.792	2.500
	15	0.434	0.804	0.473	0.836	0.690	0.839	8.302	3.929
	16	0.279	0.461	0.311	0.485	0.793	0.783	10.189	5.00
		4045-H	4046-V	4045-H	4046-V	4045-H	4040-V	4045-H	4046-V
Part A Subtraction	1	0.963	0.966	0.963	0.966	0.582	0.224	0.0	0.0
	2	0.843	0.854	0.855	0.857	0.625	0.646	1.333	0.339
	3	0.793	0.932	0.799	0.932	0.658	0.615	0.667	0.0
	4	0.790	0.719	0.801	0.724	0.654	0.683	1.333	0.678
	5	0.547	0.620	0.564	0.629	0.764	0.810	3.000	1.356
	6	0.777	0.885	0.820	0.891	0.751	0.660	5.333	0.678
	7	0.667	0.864	0.712	0.870	0.796	0.634	6.333	0.678
	8	0.520	0.600	0.559	0.608	0.841	0.808	7.000	1.356
Part B Multip.	9	0.844	0.881	0.850	0.887	0.592	0.642	0.678	0.678
	10	0.895	0.905	0.904	0.914	0.551	0.763	1.017	1.017
	11	0.892	0.834	0.901	0.845	0.582	0.676	1.017	1.356
	12	0.573	0.671	0.606	0.690	0.775	0.812	5.424	2.712
	13	0.356	0.444	0.398	0.464	0.808	0.875	10.508	5.085
	14	0.431	0.468	0.490	0.493	0.860	0.869	12.203	5.085
	15	0.356	0.464	0.412	0.498	0.792	0.749	13.559	6.780
	16	0.363	0.397	0.451	0.457	0.782	0.781	19.661	13.220

Participating Schools

Ravenswood City School District

Brentwood School

Mr. Milo Knoles, Principal

Kavanaugh School

Mr. Alfred Gordon, Principal

Costano School

Mr. Robert Guthrie, Principal

Bell Haven School

Mr. Warren Hayman, Principal

Redwood City School District

Clifford School

Mr. Frank Messer, Principal

Cupertino School District

Grant School

Mr. Victor Norton, Principal

Montclaire School

Mrs. Ethel Meehan, Principal

Dilworth School

Mr. Frank Driscol, Principal

Testing Schedule

Wednesday, March 12

Bell Haven School

10:15 - 11:25	Rooms 10, 11, 13	Grade 3
9:00 - 10:00	Rooms 17, 18, 19	Grade 4

Friday, March 14

Costano

9:00	Room 11		14 fourth graders
9:20	Room 1		11 fourth graders
9:55	Room 9	13 third graders	12 fourth graders
10:35	Room 2		15 fourth graders
10:50	Room 8	18 third graders	11 fourth graders
11:20	Room 10	16 third graders	13 fourth graders
11:45	Room 7	17 third graders	12 fourth graders
		64	88

Monday, March 17

Grant School

8:30 - 9:30	Rooms 15, 16	Grade 3
9:40 - 10:30	Rooms 1, 2	Grade 4

Tuesday, March 18

Dilworth School

10:20 - 11:10	Room 16, classes combined	Grade 3
9:15 - 10:20	Room 14, classes combined	Grade 4

Thursday, March 20

Montclaire School

8:00 - 10:15	Rooms 7, 8 ($2\frac{1}{2}$ classes)	Grade 3
10:15 - 11:30	Rooms 9, 10 ($2\frac{1}{2}$ classes)	Grade 4

Testing Schedule (continued)

Monday, March 24

Brentwood

8:00 - 9:00	Classes combined	Grade 3
9:00 - 10:00	Classes combined	Grade 4

Tuesday, March 25

Clifford School

9:00 - 10:00	Rooms 6, 7, 8	Grade 3
10:15 - 11:00	Rooms 9, 11, 12	Grade 4

Monday, April 7

Kavanaugh School

8:00 - 9:00	Classes combined	Grade 3
9:00 - 10:00	Classes combined	Grade 4

TESTS 3001, 3002, 4045, and 4046 HAVE
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